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An investigation of acoustic deterrent devices to reduce cetacean bycatch in an inshore set net fishery

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ABSTRACT

In Europe, problems with the use of pingers on larger fishing vessels have raised the question as to whether pingers would be practical on smaller vessels, which are a large proportion of the European static net fishing fleet. In this study, four netting vessels less than 10m long used AQUAmark pingers on part of their nets off the southwest coast of Britain over a 12 month period. Boat skippers recorded ease of use. Acoustic click detectors were deployed on test and control nets to assess the response of cetaceans to the pingers. No significant practical problems, apart from premature failure of pingers, were encountered. During the study, only one harbour porpoise was bycaught, in an unpingered net. In 650 days of acoustic data from pingered and non-pingered nets, matched by location, date and boat, there was a highly significant reduction in the number of porpoise clicks recorded at nets with pingers to 48% of the number predicted from the number recorded at control nets (range 35–51%). To assess habituation, single, modified pingers that were active for alternate seven hour periods were moored below a click detector at two sites, one of which has strong tides and high levels of associated ambient noise. This study showed a stronger pinger effect at the quiet site and a much reduced effect at the noisy site. There was evidence of a period of exclusion of porpoises following pinger use that could exceed seven hours, and no evidence of habituation. Results suggest that pingers are practical on small vessels, that they reduce harbour porpoise activity around nets and are therefore likely to reduce bycatch. Easier means of detecting pinger failure are needed. Pingers should be considered as a bycatch mitigation method in small vessel fisheries using bottom set nets.

KEYWORDS: BYCATCH; EUROPE; HARBOUR PORPOISE; COMMON DOLPHIN; ACOUSTICS; GILLNET FISHERY

INTRODUCTION

The incidental catch of marine mammals in fishing gear, especially static nets, is one of the greatest immediate threats to marine mammals throughout the world; the death toll from fishing nets far exceeds the deliberate take of marine mammals (Hodgson *et al.*, 2007; Reeves *et al.*, 1996). Field studies with acoustic pingers on set gillnets have shown reductions in bycatch of harbour porpoise (*Phocoena phocoena*) in a sink gillnet fishery (Kraus *et al.*, 1997; Trippel *et al.*, 1999) and of common dolphins (*Delphinus delphis*) in a drift net fishery (Barlow and Cameron, 2003). There have also been a number of studies of the effectiveness of acoustic alarms using simulations at sea (Carlström *et al.*, 2009; Cox *et al.*, 2003; Culik *et al.*, 2001) and studies of their effects on captive animals (e.g. Kastelein *et al.*, 2000) and in the wild (Culik *et al.*, 2001). These successful trials of acoustic alarms contributed to the introduction of European Union Council Regulation No 812/2004 that made the use of acoustic deterrents (pingers) mandatory in certain areas on vessels larger than 15m in length using static bottom set fishing nets. Since this legislation was passed, practical problems in using pingers on these vessels have emerged (Caslake and Lart, 2006) and few vessels are currently using them. EUC Regulation 812/2004 imposes no direct action to reduce cetacean bycatch on vessels of less than 15m, but does require appropriate monitoring of their bycatch.

Globally, there is extensive evidence that cetacean bycatch occurs in many areas where gill or tangle net fisheries occur within cetacean habitats (Perrin *et al.*, 1994). In Cornwall there is also evidence of a major decline in small cetaceans during the second half of the 20th century (Tregenza, 1992).

This study was undertaken in Cornwall, in the southwest of the UK mainland. The adjacent Celtic Sea region has a documented porpoise bycatch in gillnets estimated in 1992 at around 2,200 animals per annum (Tregenza *et al.*, 1997). The Cornwall Wildlife Trust Marine Strandings Network (CWT MSN) annual report for 2007 identifies 75% of harbour porpoises (*Phocoena phocoena*) examined as showing signs of having been bycaught in gillnets/tangle nets (Loveridge and Loveridge, 2007).

Cornwall has a small, but well recognised, resident group of inshore bottlenose dolphins (*Tursiops truncatus*), which has shown a decline in the average observed group size over the last 17 years to levels at which the loss of any individual will have a significant impact on the survival potential of this group (Wood, 1998). The UK Stranding Investigation Programme Report for 2009 documents the cause of death of one of the two bottlenose dolphin strandings, in Cornwall, during this year as due to net entanglement.

The southwest of the UK has over 500 registered inshore vessels with licenses (data from Marine Management Organisation) allowing them to deploy bottom set gillnets.

METHOD

The fishery

The nets used most by small vessels in Cornwall are tangle nets, commonly termed ‘monk nets’. Tangle nets generally consist of 267mm mesh monofilament netting with a leaded

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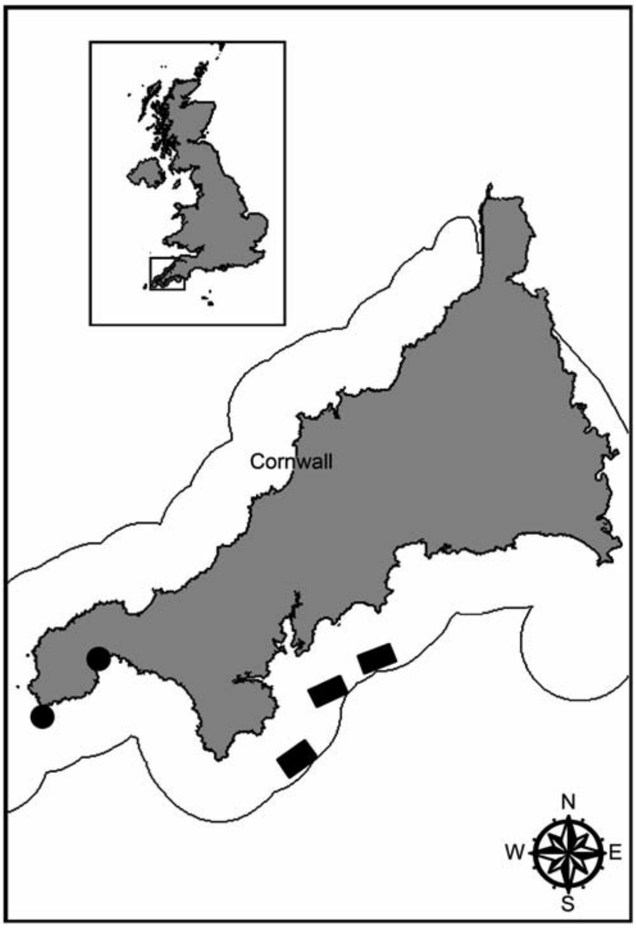

Fig. 1. Approximate areas (squares) of fishing effort in relation to the six nautical mile limit and points showing cycling pinger deployment.

footrope and a headline with no, or minimal, buoyancy, usually with a hanging ratio of 0.3[1] to target benthic species such as monk fish *(Lophius americanus)*. These nets are pushed flat onto the seabed in tidal currents. They are set for approximately five days 'soak time' depending on weather conditions at depths ranging from 20 to 100m. The fishery operates throughout the year.

Four commercial fishing vessels less than 10m in length setting monk nets volunteered to take part in this trial. All nets were deployed within a day's steam of the home port and within the six nautical mile limit (Fig. 1).

Test nets were equipped with pingers spaced at 200m intervals. Fishermen were asked to keep the control nets at least one nautical mile away from test nets. Each skipper was entirely responsible for deploying and recovering the equipment with their fishing gear while continuing with normal fishing activity in order to test the practical aspects of using pingers during normal working conditions. Where possible, skippers were requested to deploy test and control nets on the same days. Skippers recorded any cetacean bycatch with the date, time, position and possible species.

Pingers

The pinger used in this study was the AQUAmark 100, which is an acoustic pinger designed and produced by AQUATEC (*http://www.aquatecgroup.com*). The AQUAmark 100 has a wideband, frequency modulated, ping within the range of porpoise hearing (pings: 20–140 kHz). The pings last 0.4 seconds, and are repeated at random intervals between 4 and 15 seconds. They are in accordance with Set 1 of EUC Regulation 812/2004.

Fig. 2. Pinger attached to foot rope of static netting.

Click detectors

Acoustic click detectors, (C-PODs, Chelonia Limited UK) were used to assess the response of cetaceans to the pingers. C-PODs are fully automated, static, passive acoustic monitoring systems that detect echolocating odontocetes by recognising their ultrasonic sonar click trains and distinguishing these from the sounds made by boat echo-sounders and other sources. The system achieves sufficiently low false positive rates to allow its use in areas of very low cetacean density (Verfuss *et al.*, 2007). Each vessel in the trial was equipped with two C-PODs, which were deployed at the end of 1km tiers of monk net, one of which was equipped with active pingers. The approximate detection distance for harbour porpoises by a C-POD is c.500m.

Visual validation, using a method based on Verfuss *et al.* (2004), of automated identification of porpoise sonar in the data showed few false positives. The analysis here is solely of porpoise detections as only 170 minutes of encounters with dolphins (probably common or bottlenose dolphins) were recorded throughout the trial.

As the daily detection rates are influenced by the seasonal pattern of porpoise activity (which is not naturally symmetrically distributed around the mean or median) the pinger effect was assessed using a sign test of the fraction of days in which the number of clicks detected on pingered nets exceeded the number of clicks detected on control nets. The test was performed as a two-tailed test.

To investigate changes in behaviour caused by the pingers, the ratio of loud clicks to weak clicks was considered. The presumption was made that loud clicks indicated animals close to the C-POD. The estimated extreme maximum range of detection for the C-POD is probably 300–400m for harbour porpoises. The C-POD has a sound pressure scale limited to 25 Pascals peak-to-peak. Many received clicks exceed this upper limit but their amplitude is recorded as the scale maximum, which is nominally 255. 'Weak clicks' were defined as having scale amplitudes of less than 127, while 'loud clicks' were defined as having amplitudes greater than 127.

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[1] i.e. The length of the fishery net when made up divided by the length of the original sheet of netting.

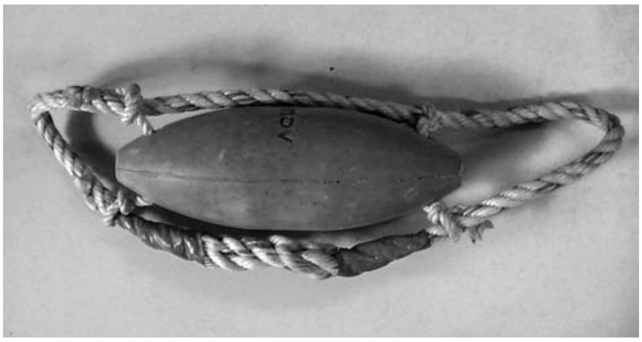

Fig. 3. Pinger tied into rope loop ready to be attached to netting.

Static mooring trials

A small number of pingers were modified to have a seven hour cycle of normal pinging alternating with seven hours with no pings. The seven hour cycle was chosen to ensure that tidal and diurnal effects could not remain synchronised with the cycle of pinger activity. This experimental method was first used by Carlstrom *et al.* (2009). These 'cycling' pingers were deployed on longer term fixed moorings, with a C-POD but with no associated net. One was deployed in Mounts Bay on the south coast of Cornwall (50°06'44.69N, 05°28'45.23W) a site with low tidal flows, and one on the Runnelstone reef, a location further west with fast currents and moving sand creating high levels of ambient noise.

RESULTS

Practicality of pinger deployment

The pingers were placed on the footrope of the net, at the junction between panels of net that are typically around 100m long. Initially there were concerns with tangling of the nets from the addition of pingers. However a successful method of rigging the pinger was developed quickly by the skippers and worked well (Figs 3 and 4).

The majority of problems reported with tangling were at the beginning of the trial and were relatively small. Only one major tangling incident occurred which was due to buttonholing (where the pinger drops through the mesh of lower layers of net on deck and then tangles the net on re-deployment). This incident resulted in fishing effort being stopped for approximately 30 minutes.

All data were collected over a 12 month period. One of the four boats did not produce any paired data (where acoustic data is available for both the test and control nets on the same day).

The four boats acoustically monitored 1,150 days of soak time (i.e. time during which nets are in the water) between April 2009 and April 2010, of which 640 days had data from C-PODs on both pingered and non-pingered nets set by the same vessel on the same day.

Cetacean bycatch

Four porpoise and no dolphin bycatches were recorded during the trial. Only one bycaught animal was from an acoustically monitored experimental net, and this was a non-pingered net.

Acoustic data: pingers on nets

Acoustic data were analysed as clicks per day, identified by the C-POD software, and validated by visual inspection of the raw data. The data showed that the rate of recording harbour porpoise clicks at nets with pingers was between 35–51% of the rate at control nets (Table 1). Reduction in detections when pingers are active was highly significant (two tailed sign test $p < 0.001$). No significant difference was found in the proportion of weak or loud clicks logged when the pinger was active. At the end of the working trial, 7 of the 23 pingers were found to be inactive. The time of failure is not known as the pings are ultrasonic (i.e. not audible) and the pingers were not otherwise tested during the trial.

Static mooring trial

Cycling pingers were deployed at two sites, one in Mounts Bay and one off on the Runnelstone Reef (see Fig. 1). These sites differed considerably, with the Runnelstone Reef area being subject to strong tidal currents and prevailing swell, whereas the Mounts Bay site is a relatively quiet site with weaker tidal flows. Data collected from the respective sites varied considerably (Table 2) The pinger at the quiet site failed after 48 days and provided a single unplanned test of the 'recovery time' before the return of animals after the end of pinger activity.

The Mounts Bay pinger worked for 53 days during which

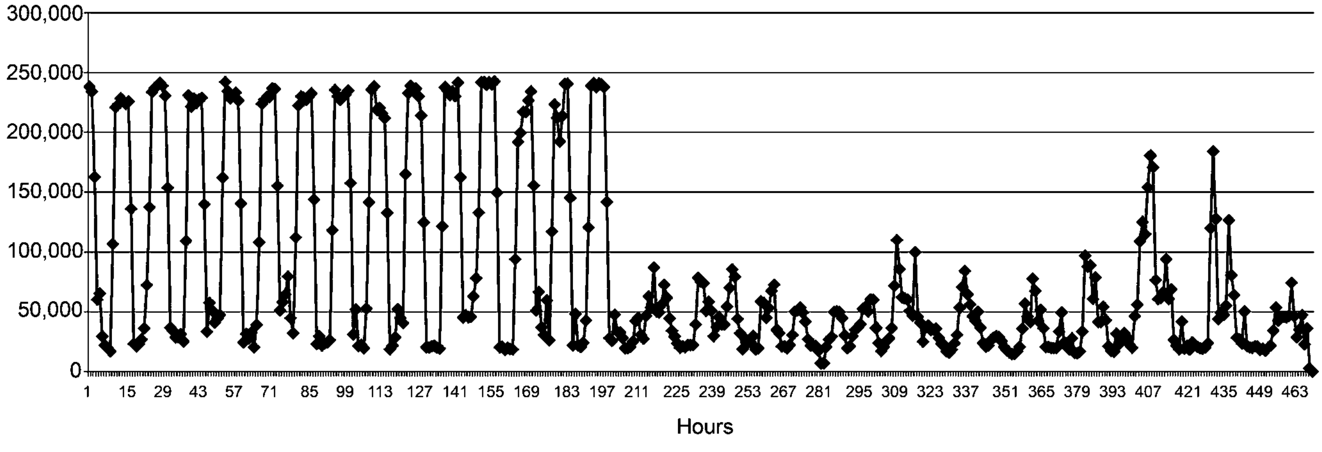

Fig. 4. Number of clicks per hour for one week before and after pinger failure, showing the clear seven hour cycle of the pinger before failure.

Table 1

Number of clicks recorded on test and control nets per vessel.

Vessel	Clicks logged: non-pingered nets	Clicks logged: pingered nets	Pingered net clicks as % of non-pingered nets
1	7,856	2,727	35%
2	39,960	20,371	51%
3	1,946	802	41%
All vessels	49,762	23,900	48%

time six OFF periods had harbour porpoise detections but there were none during ON periods (Table 3). In Mounts Bay data pinger pings are clearly recorded by the C-POD, and ended abruptly on 12 July 2010 at 06:32. The hourly acoustic record for the week before and after the end of pinger activity is shown in Figs 4 and 5. The large peaks in the click counts in the lower panel show the periods when the pinger was active. Following the pinger failure a weaker tidal/diurnal cycle in ambient noise is seen, and there are more porpoise detections. We cannot, on the basis of this single unscheduled test, exclude the possibility that this change was coincidental.

Most acoustic encounters consist of several trains of clicks detected as the sonar beam of the cetacean sweeps across the logger during the period that the animal is within detection range. An autocorrelation of the detection times of clicks at each site showed a fall to below the 5% level of significance (2/sqrt (N)) at five minutes. This is an indication of the duration of a porpoise visit to the pinger locality. The seven hour ON or OFF half-cycles in the Mounts Bay data were analysed using simple probabilities on the basis that half-cycles of either phase were independent samples. The mean rate of detection was 6 in 98 half-cycles. The probability of no detection in seven hours was 0.9388 giving, for the 49 successive seven hour periods with no detection, a significant one-tailed probability of 0.045.

The Runnelstone reef data showed that the pinger was deployed and was still working at 81 days when the C-POD memory filled to capacity and logging was ended. The results were surprising when compared to the Mounts Bay site. Where the Mounts Bay data showed nearly complete exclusion (or non-vocalisation) even during the OFF periods of harbour porpoises within a C-POD detection range of the pinger, the Runnelstone data showed more porpoise activity and a strikingly smaller difference between the two phases of the pinger cycle.

At the Runnelstone site ON periods with porpoise activity were 49% of the fraction of OFF periods that were porpoise-positive giving a significant two-tailed p value of < 0.001 using the sign test.

Acoustic data: habituation

Habituation could not be tested on the net data as the location of the nets was not controlled. Too few detections were made during the active life of the Mount's Bay cycling pinger to assess any trend. At the Runnelstone site a linear regression on the number of clicks detected per day showed a fall of 57% during the 81 day period monitored. This may be a seasonal pattern. The rate of fall, assessed by linear regression, was higher in ON periods than in OFF periods, giving no evidence of a reducing pinger effect which would be expected to appear as a reduced rate of fall during ON periods.

DISCUSSION

Practical issues of pinger use in the fishery

Hauling and shooting of nets differs on these small vessels from the larger offshore vessels studied in a Seafish pinger trial (Caslake and Lart, 2006) in that the nets are shot from the stern directly from net bins or from the deck, without going through a tube, and are recovered using smaller haulers than on the larger vessels. Once the net has been hauled and the fish picked out, the nets are put through the flaking machine, which helps lay the nets in a bin with the headline and footrope separated and ready for a clean deployment (Caslake and Lart, 2006).

The method of rigging the pingers as developed during the trial worked well and there were few concerns about using the pingers by the end of the trial. Caslake and Lart (2006) reported that on larger offshore vessels pingers were caught up and shot out at high speed in the direction of the crew member working the flaking machine. This problem was not apparent on the smaller vessels in this trial due to different placements of the equipment and crew. The problems of tangling encountered on larger vessels were also greatly

Table 2

Loud clicks recorded on test and control nets.

Vessel	Loud clicks non-pingered nets	Loud clicks pingered nets	Pingered net loud clicks as a % of non-pingered net	Weak clicks non-pingered nets	Weak clicks pingered nets	Pingered net weak clicks as a % of non-pingered net
1	1,678	359	21%	6,178	2,368	38%
2	8,133	4,600	57%	31,827	15,771	50%
3	282	116	41%	1,664	686	41%
All	10,093	5,075	50%	39,669	18,825	47%

Table 3

Percent of clicks during the on cycle of modified pingers.

Static mooring site	Number of ON/OFF cycles	A = ON cycles with porpoise detections	B = OFF cycles with porpoise detections	A as % of B
Runnelstone reef	281	124	251	49%
Mounts Bay	49	0	6	0%

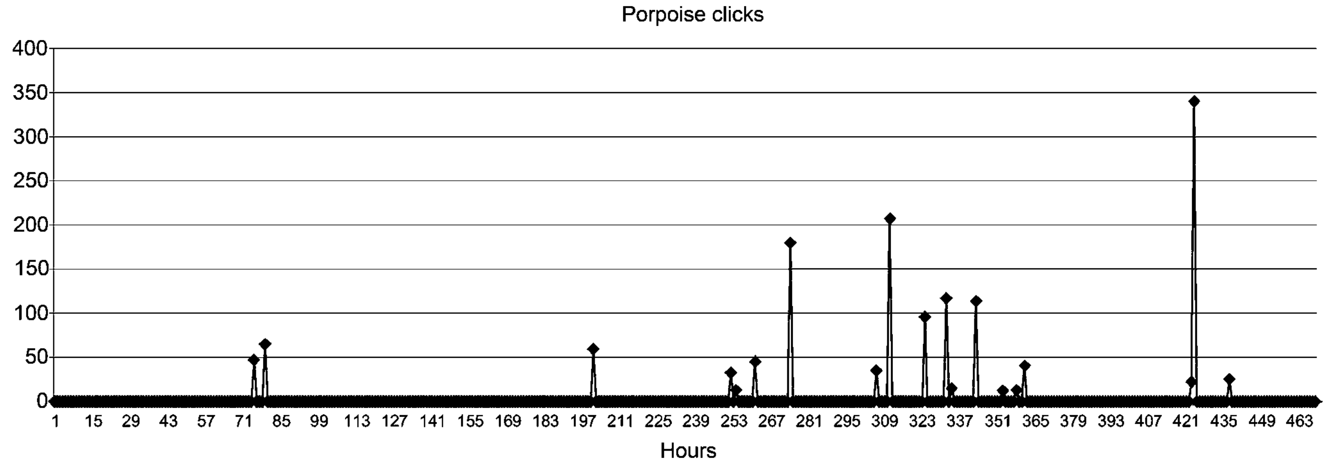

Fig. 5. Porpoise click detections per hour for one week before and after the pinger failure.

reduced in this trial, due to the smaller lengths of nets and the use of net bins.

The placement of pingers on the footrope rather than the head rope of the set nets used in this trial has the following advantages: the head rope is not pulled down by the weight of the pinger; the pinger contributes usefully to the weight of the footrope; it may reduce the risk of 'button-holing' during deployment; and there is usually less tension on the footrope during hauling, putting less stress on the pinger. There has been concern that pingers on the bottom will be less audible to porpoises, but as these nets are deployed on a predominantly even sea bed a major effect is unlikely.

Concerns raised by the skippers taking part in the trial were mainly about the battery life of the pinger and the cost of putting them on all their fishing gear, rather than any other practical problems. These concerns were confirmed when pingers were recovered at the end of the trial and 7 out of 23 were found to be inactive, most likely due to flat batteries as no external damage was observed.

Skippers found some difficulties in deploying the C-PODs on working nets because of their large size (90×800mm), but despite these difficulties they did obtain a substantial volume of useful data.

Pinger effectiveness

The data presented show a marked decrease of acoustic activity around those nets equipped with pingers. This was mirrored by the static cycling pinger deployments, but these showed a marked difference in the size of the effect. The most plausible explanation of the difference between the two cycling pinger deployments is a reduced response to pingers where background noise is louder. This may have implications elsewhere and merits further investigation.

The difference between static cycling pingers and those deployed on nets may also in part be due to pingers losing power or failing during the net trial so that some 'pingered' data may have come from nets where the pinger is silent. There may also have been some deployments in which the C-POD was more distant from the nearest active pinger than expected (there was some evidence for this in acoustic data files in which pinger activity could not be identified where it was expected).

Analysis of the loudness of clicks recorded showed no significant indication that porpoise echolocation varied with the presence of pingers. It is possible that porpoises echolocate more loudly in response to the pinger, as they can vary the sound pressure level of their clicks over a wide range (Villadsgaard *et al.*, 2007). It was not possible to make any inference from the acoustic data on the extent of displacement of the porpoises by the pinger.

The failure of several pingers may have been due in part to the immersion switch on the AQUAmark 100 being ON during net storage in bins in which they do not fully dry out, however the manufacturer's specification states a lifetime of one to two years with continuous immersion, dependent on temperature, or up to four years in a typical fishery with seasonal or discontinuous deployment. The specified lifetime should have covered the whole of this trial.

Palka (2008) reports evidence that porpoise bycatch in the US Northeast gillnet fishery in New England, where pingers are mandatory, is not as low as earlier trials suggested it would be, and concluded that inactive or absent pingers were a major part of the explanation plus a possibility that gaps in a line of active pingers may actually increase bycatch. The present study, and those findings, indicate that pinger monitoring needs to be simpler.

Habituation and recovery times

It has been a source of quite widespread concern that pingers might impede the movement of porpoises or exclude them from critical habitat (e.g. Cox *et al.*, 2001). No evidence was seen of habituation to the pinger which is consistent with the findings of Palka (2008). Further studies with cycling pingers could be made at low cost using the same study design and would be valuable in establishing the recovery time more accurately. The seven hour cycle used here was probably too short to allow 'recolonisation' of the exclusion zone in the quiet site, but was not too short in the noisy site.

CONCLUSIONS

This study has shown that functioning pingers are likely to reduce harbour porpoise bycatch rate in this inshore tangle net fishery. It seems unlikely that habituation will become a problem for harbour porpoises although further work is needed to demonstrate this.

Further work is urgently needed to investigate the life-time of available pingers in real time fisheries. Cycling pinger trials, with a longer activity cycle, could identify recovery time, the possible effects of ambient noise, habituation and the response of dolphins more accurately. The cycling pinger trial design used here proved to be an efficient and very low cost method of assessing responses to man-made sounds.

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